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## Identifying endocarp remains and exploring their use at Epipalaeolithic Öküzini in southwest Anatolia, Turkey

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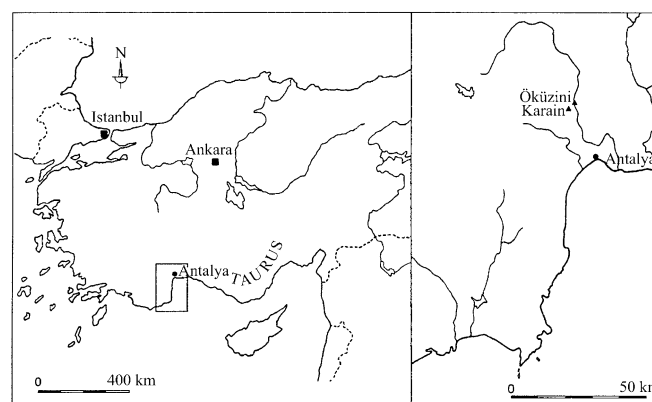
**Abstract** Excavation of the Epipalaeolithic levels of the cave site Öküzini in southwest Anatolia produced many “nutshell” remains, mainly endocarp fragments belonging either to *Prunus* or *Amygdalus*. Morphological comparison with the range of potential species and present geographical distribution made it possible to refine the determination to either of two species of wild almond, *Amygdalus orientalis* or *A. graeca*. These plants could grow in the surroundings of the site on rocky slopes or sandy hills and had to be collected during late summer. All wild *Amygdalus* seeds are toxic, so that their use as food is disputed. This paper explores the detoxification possibilities, nutritional properties and ethnographic analogies for the use of wild almonds. It comes to the conclusion that the seeds probably played a notable role in the diet of the Epipalaeolithic population of southwest Anatolia, complementing meat and other plant food. An examination of further prehistoric “nutshell” finds from Anatolia supports a long and widely distributed tradition of almond use.

**Keywords** *Amygdalus* · *Prunus* · Endocarp identification · Wild-food gathering · Detoxification · Epipalaeolithic · Turkey

### Introduction

During the excavations of the small Öküzini cave (37°05'N, 30°32'E), a remarkable assemblage of carbonised plant macroremains has been recovered (Martinoli 2002). The cave is set in southwest Anatolia some 300 m above sea level (Fig. 1). Located at the foot of the Katran Mountains with summits reaching more than 2,000 m, it opens onto an alluvial plain overlooking

Antalya. The site was discovered and first excavated in the 1950s and an additional excavation led by Prof. Yalçinkaya (Ankara University) and Prof. Otte (Liège University) lasted from 1989 to 1999 (Yalçinkaya et al. 2002). The 3.5 m thick deposits contain an archaeological sequence starting with the final Palaeolithic, followed by thick Epipalaeolithic layers (Otte et al. 2003). Several Neolithic and Chalcolithic burials were present at the top of the sequence, cut into the underlying deposits. The sequence is interrupted by three sedimentary gaps (Otte et al. 2003). The cave bears traces of intense human activity: hearth stones, combustion zones filled with ash deposits, extremely abundant lithic material (including grinding stones) and faunal debris are found throughout the stratigraphic sequence. The site was often reused, probably as a seasonal campsite (Atıcı and Stutz 2002). Based on the archaeological assemblages, six occupation phases (also called anthropological phases) have been distinguished: units I to IV belong to the Epipalaeolithic industry, V and VI have Neolithic and Chalcolithic components (Otte et al. 2003). The dates range from 16,560±180 uncal B.P. (18,200–17,400 cal B.C.) to 12,130±100 uncal B.P. (14,400–11,800 cal B.C.) for the



**Fig. 1** Location map of Öküzini Cave

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Epipalaeolithic levels. The upper deposits gave a date of  $7,880 \pm 80$  uncal B.P. (6,840–6,640 cal B.C.).

Only a limited number of Epipalaeolithic sites in the southeast Mediterranean and southwest Asia have yielded botanical remains. These are Hallan Cemi in Turkey (Rosenberg et al. 1995, 1998), Franchthi and Theopetra caves in Greece (Hansen 1991; Kyprissi-Apostolika 1999), Abu Hureyra and Mureybit in Syria (van Zeist and Bakker-Heeres 1984/1986; Hillman 2000), Ohalo II, Nahal Oren and Hayonim caves in Israel (Noy et al. 1973; Hopf and Bar-Yosef 1987; Kislev et al. 1992), Wadi Hammeh 27 and Wadi Jilat 6 in Jordan (Colledge 2001). While the concentration of seeds and fruits found at Öküzini is modest, the tough fragments of fruitstones are well represented, in particular endocarp fragments belonging either to *Amygdalus* or *Prunus*. Studies on morphological identification of *Amygdalus* and *Prunus* endocarps in southwest Asia are scarce. The rarity of large and well-preserved finds might be one reason. The high diversity and great variability of this taxonomic group could be another. The latter makes a secure identification, sometimes even of the whole plant, difficult. An attempt to use chemical analysis on similar kinds of fossil remains has given promising results, but has not been further explored (McLaren 1995). Although the genera *Prunus* and *Amygdalus* have been identified among the wood charcoals and pollen recovered in the Epipalaeolithic levels in Öküzini (Thiébaud 2002; Emery-Barbier 2002), the identification to a group of species, or to a species, was impossible. A more accurate determination of the endocarps recovered will enhance the comprehension of their role (in *Prunus*, the fleshy fruits

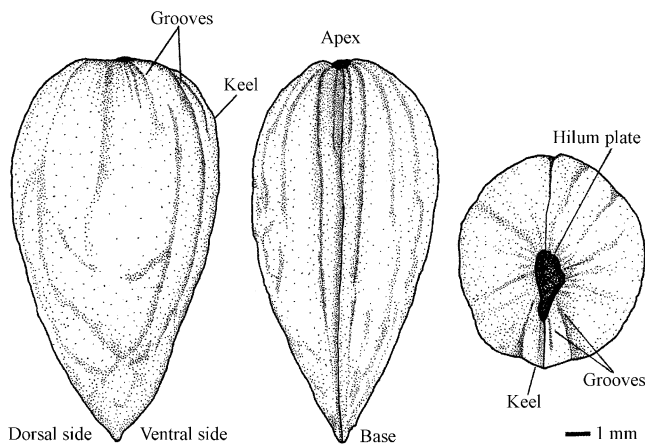
and nutty seeds within the fruitstones can be consumed, in *Amygdalus* only the nutty seeds), the season of availability and the ecology of this resource. The wild nuts and fruits uncovered in archaeological layers have usually been considered as food resources. In the case of wild plants which are somewhat toxic, as is the case with the *Prunus* and *Amygdalus* seeds, their past use as food is a controversial point (Ladizinsky 1999). Direct proof for consumption of the seeds of the fossil endocarps is seldom found and their presence on a site can be the result, for example, of their accidental gathering with wood for fuel. In this paper we will use indirect paths to argue in favour of an important role, as a complement to meat, of the *Amygdalus* and/or *Prunus* seeds in the diet of the Epipalaeolithic dwellers of Öküzini, by exploring the nutritional properties of the endocarps identified and ethnographic analogies. A close examination of similar “nutshell” remains and their recovery context in other pre-agrarian and agrarian sites in Anatolia will also support our hypothesis.

## Materials and methods

The excavation area was dug with 10 cm thick arbitrary spits in 50×50 cm squares. In order to maximise retrieval of plant remains, all the deposits were processed by bucket flotation and sieved on a 0.5 mm sieve (Martinoli 2002). The inorganic sediments left as residues after flotation were sieved and split in 4, 2 and 1 mm size fractions and sorted with the naked eye. As a result of the excavation strategy, mixed spits, especially in the upper levels, occur and had to be eliminated from this study. Fortunately, because of the more or less horizontal deposition of the sediments,

**Table 1** Provenances and collection numbers of the *Amygdalus* and *Prunus* specimens examined

Species	Collection	Provenance
<i>Amygdalus fenzliana</i> (Fritsch) Lipsky	Felipe and Grasselly, Zaragoza	Iran
<i>Amygdalus webbii</i> Spach	Felipe and Grasselly, Zaragoza	Toledo, Spain
<i>Amygdalus webbii</i> Spach	Felipe and Grasselly, Zaragoza	Sicily, Italy
<i>Amygdalus zabulica</i> Searf.	Felipe and Grasselly, Zaragoza	Kabul province, Afghanistan
<i>Amygdalus kuramica</i> Korsch.	Felipe and Grasselly, Zaragoza	Salang, North Afghanistan
<i>Amygdalus kuramica</i> Korsch.	Felipe and Grasselly, Zaragoza	Tcharatou Ghazmir, Afghanistan
<i>Amygdalus kuramica</i> Korsch.	Felipe and Grasselly, Zaragoza	Shah Maksud, Afghanistan
<i>Amygdalus bucharica</i> Korsch.	Felipe and Grasselly, Zaragoza	Khulm, Afghanistan
<i>Amygdalus bucharica</i> Korsch.	Felipe and Grasselly, Zaragoza	Balkh, Afghanistan
<i>Amygdalus bucharica</i> Korsch.	Botanical Institute Basel	Botanical garden Frunse, Kirgistan
<i>Amygdalus orientalis</i> Duhamel	Botanical Institute Basel	Konya province, Karadağ, Turkey. <i>Legit</i> Aylan Erkal
<i>Amygdalus orientalis</i> Duhamel	University College London	Polatlı province, Turkey. <i>Legit</i> Gordon Hillman, GCH3270
<i>Amygdalus orientalis</i> Duhamel	Botanical Institute Basel	Ankara province, Cubuk Barajı, Turkey. <i>Legit</i> Mark Nesbitt RMN1735
<i>Amygdalus graeca</i> Lindley	Hacettepe University Herbarium	Antalya, Kumluca, Altınyaka road, serpentine, phrygana, 300 m, <i>Legit</i> Ali Dönmez AAD3970
<i>Amygdalus scoparia</i> Spach	Felipe and Grasselly, Zaragoza	Between Sahrekord and Ispahan, Iran (planted)
<i>Amygdalus scoparia</i> Spach	Botanical Institute Basel	Botanical garden Teheran, Market, Iran
<i>Amygdalus georgica</i> Desf.	Botanical Institute Basel	Botanical garden Tbilisi, Georgia
<i>Amygdalus spinosissima</i> Bunge	Felipe and Grasselly, Zaragoza	Zaragoza, Spain (planted)
<i>Amygdalus spinosissima</i> Bunge	Felipe and Grasselly, Zaragoza	Shah Maksud, Afghanistan
<i>Amygdalus brahuica</i> Boiss.	Felipe and Grasselly, Zaragoza	Salang, North Afghanistan
<i>Prunus divaricata</i> Led.	Botanical Institute Basel	Botanical garden Erevan, (wild)
<i>Prunus divaricata</i> Led.	Botanical Institute Basel	Sofia, Bulgaria (wild)
<i>Prunus divaricata</i> Led.	Botanical Institute Basel	Botanical garden Izmir, Spiladağı, Turkey
<i>Prunus divaricata</i> subsp. <i>ursina</i> (Kotsch.) Browicz	University College London	Turkey. <i>Legit</i> Sebastian Payne, SP156

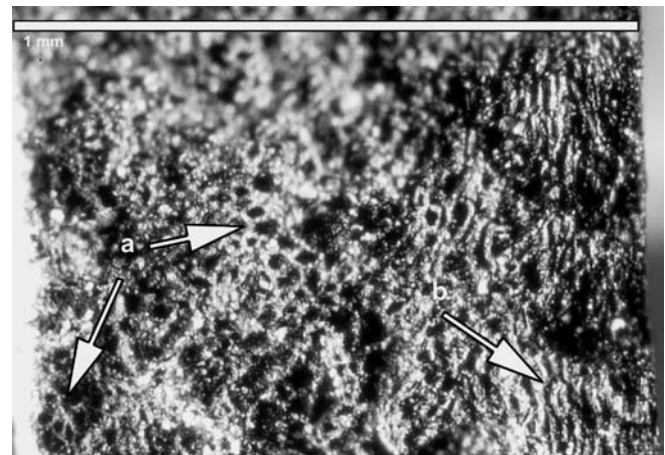


**Fig. 2** Modern *Amygdalus graeca* Lindley (Hacettepe University Herbarium AAD 3970) with the essential features of *Amygdalus* and *Prunus* endocarps

only arbitrary spits overlapping two different geological horizons (GH) had to be eliminated. This study includes the botanical remains from the levels attributed to the Epipalaeolithic period (anthropological phases I to IV; Otte et al. 2003), from which more than 4,000 litres of sediments have been processed. The “nutshell” remains, including endocarps, uncovered in Öküzini were identified by comparing their morphology and anatomy (in particular the cell structure of the transverse section) to those in modern specimens. A binocular (Wild M3Z 6–40 X; Leica MZ125 8–100 X), a reflection microscope (Laborlux 12ME 200–500 X) and a scanning electron microscope (SEM Laboratory University College London) were used. The “nutshell” remains could easily be separated into a *Pistacia*, a *Quercus* and an *Amygdalus* or *Prunus* category. The specific identification of this last group was the most problematic because of the number of potential species and the difficulty in examining an exhaustive endocarp collection of *Amygdalus* and *Prunus* from southwest Asia. In addition, the high interspecific similarity, the possibility of hybridisation and the confusion in the taxonomy makes it even more difficult. Despite the examination of different specialised seeds and fruits collections (Botanical Institute Basel, University College London, British Institute of Archaeology Ankara, Institute of Mediterranean Agriculture Zaragoza), the range of modern endocarps studied remains incomplete (Table 1). Additional collections are dispersed between different countries and it was not possible, within the scope of this study, to consult them all. As a consequence, the descriptions of the modern endocarps had to be completed with those found in the literature (Meikle 1966; Browicz 1969; Browicz 1972a, 1972c; Grasselly 1976a; Grasselly and Crossa-Raynaud 1980; Browicz and Zohary 1996).

The essential morphological features of *Amygdalus* and *Prunus* endocarps (Fig. 2) are their shape and size, the arrangement of the ventral and dorsal sutures and the surface pattern, the latter being the most characteristic feature, even when, unfortunately, it is not always constant (Browicz 1969). The ventral suture is generally well built, more or less protruding and sharp, composed of lips outlined by the vascular bundles. Laterally, the vascular bundles diverge into secondary bundles, the imprints of which induce more or less reticulate, pitted, rugulate, grooved or areolate sculptures over the endocarp. The texture of the endocarp shell itself varies from dense to fibrous, with vascular bundles included in the shell or not.

In this paper, we follow the taxonomy and nomenclature from the Flora of Turkey and the East Aegean Islands (Davis et al. 1965–1988) and the latest revision of the *Amygdalus* genus (Browicz and Zohary 1996).



**Fig. 3** Anatomical structure of the transverse section of an endocarp fragment from Öküzini. *a*, rounded cells, *b*, tangentially elongated cells (Photograph G. Haldimann)

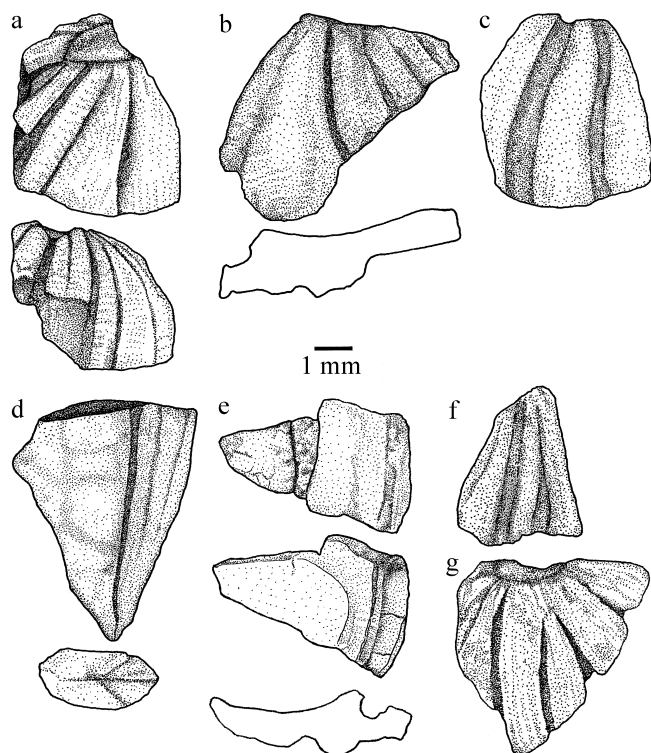
## Results

### Description of the plant finds from Öküzini

Around 1,280 carbonised fragments of different size and shape (the largest measuring 5 by 5 mm) attributed to endocarps were recovered. They were accompanied in the samples by other “nutshell” and fruit remnants (like *Pistacia*, *Quercus*, *Crataegus*, *Celtis*, *Pyrus*, *Rosa* and *Vitis*), wood charcoals, indeterminate residues belonging probably to roots or tubers, and some sporadic small seeds (*Alkanna*, *Galium*, Poaceae, Cyperaceae, Trifolieae). The endocarp fragments possessed smooth borders, so that they were probably fragmented before carbonisation and deposition in the sediments. The features they share are a 0.8 to 1 mm thick shell with a similar histological arrangement in transverse section: the endocarps are composed of an outer layer of rounded cells with thick walls and small lumen irregularly arranged, and an internal layer made up of tangentially elongated cells (Fig. 3).

Different types of fragments could be observed according to the part of the endocarp they came from or to their preservation state (Fig. 4). The fragments originating from the surroundings of the hilum plate bore deep and more or less thick grooves (Fig. 4a,b,c,f,g). They were curved, reflecting a rounded, though laterally slightly flattened, hilum apex. Some of them comprised parts of the round-elongated hilum plate (Fig. 4a,g). Other fragments comprised segments of the ventral keel, which were well individualised and sharp (Fig. 4a,b,d,e). A strong main groove delimited the keel on each side, bordered by one, sometimes two, weaker grooves incising the lips. In cross-section, the cavity of the main vascular bundle was visible in the centre of the keel or slightly displaced to the inner side (Fig. 4e). Many fragments came from the flanks of the endocarps and differed only through their ornamentation, which could be longitu-





**Fig. 4a–g** Fossil endocarp fragments uncovered from Öküzini. **a** fragment with hilum plate and keel; **b** fragment from the apex with keel, grooves and main vascular bundle cavity; **c** fragment with grooves; **d** pointed base fragment with keel; **e** fragment from the middle of the endocarp, with keel and main vascular bundle cavity; **f** fragment with grooves; **g** fragment with hilum plate and grooves

nally grooved, reticulate or smooth. Some pieces came from the basal extremity: they were laterally flattened and pointed (Fig. 4d).

Additional fragments with similar anatomical structure were small or eroded and lacked any ornamentation. The fragments were usually slightly curved.

#### Identification of the *Prunus*/*Amygdalus* endocarps

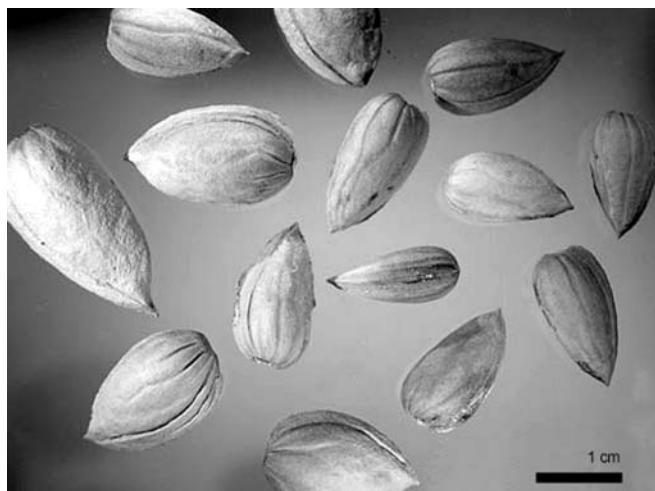
The lack of whole specimens in the assemblage makes a specific identification difficult. However, the simultaneous presence of the various fragments and several overlapping anatomical and morphological features, induce a high probability that the fragments belong to endocarps from the same species. So, when considering the whole range of features shared between the different fragments, it should be possible to refine the identification to a species or at least to a group of species. The modern natural geographical distribution of the plants can also be of some help, although it must be kept in mind that the present distribution is the result of the woodland expansion, which started at the Pleistocene/Holocene transition, and partly human impact. Therefore, present distribution areas have been considered very broadly.

As already mentioned, the endocarp fragments belong either to *Prunus* or *Amygdalus*. According to shape and ornamentation, the genus *Padus* and *Cerasus* could be eliminated from the possible identifications. Among the five *Prunus* species occurring in Turkey (Browicz 1972c), only the *Prunus divaricata* endocarps offer some similarity with the remains recovered. Their endocarps can be smooth or scabrous and they have sometimes very shallow sub-marginal furrows (Meikle 1966; Browicz 1972c), but are never grooved. The hilum extremity can be blunt or elongated and the endocarps are usually laterally compressed and sulcate (grooved).

The genus *Amygdalus* is divided into two subgenera, subg. *Amygdalus*, which is large and diverse and includes three sections, and subg. *Dodecandra*, which is small, uniform and consists of only five species. Subgenus *Amygdalus* is composed of the sections *Amygdalus*, consisting of the *Communis* and the *Orientalis* species groups, *Chamaeamygdalus*, and *Spartioides*. So, the genus *Amygdalus* contains five natural groups, each representing a cluster of taxonomically closely related, largely vicarious species. Within each such natural group, member species seem to be fully (or almost fully) interfertile, but they occupy separate geographic territories (Browicz and Zohary 1996). Many species are an unlikely identification because of their morphology and/or irrelevant distribution area.

Five of the nine species in the *Communis* species group have a pitted or partially pitted shell (*Amygdalus communis*, *A. trichamygdalus*, *A. fenzliana*, *A. webbii*, *A. browiczii*). The four remaining species have a distant distribution area (*Amygdalus hausknechtii*, *A. kuramica*, *A. bucharica*, *A. tangutica*). Moreover, some of them have a distinct morphology like the typical sculpture for *Amygdalus kuramica*, superficial and weak grooves for *A. bucharica* and a roughened endocarp for *A. tangutica* (Kester and Gradziel 1996). The species from the *Communis* group can therefore be excluded from a possible identification.

In the *Orientalis* group, the species *Amygdalus orientalis* has an ovoid, elongated, up to 19×10 mm endocarp. The hilum plate is oval. The keel is sharp, protruding and bordered with one deep and broad groove on each side over the whole length of the endocarp. Sometimes a secondary, longitudinally weaker groove is present in the upper half of the lips. The surface pattern is composed of longitudinal grooves starting around the hilum plate and getting weaker on the flanks (Fig. 5). In some cases, these grooves can make ramifications on the flanks and form a dense reticulate pattern. *Amygdalus graeca* is a species closely related to *A. orientalis*, or not completely separated from each other (Ali Dönmez, pers. comm.). According to the descriptions found (Browicz 1972a; Browicz 1972b), its endocarps are highly similar, though smoother, and the keel is usually less strongly built (Fig. 2). There is a variation in stone shape and ornamentation in both species. *A. kotschyi* has a pitted endocarp (Antonio Felipe, pers. comm.). The three remaining species show very confined (*A. eleagnifolia*,



**Fig. 5** Modern *Amygdalus orientalis* Duhamel endocarps (University of Basel Collection RMN1735)

*A. carduchorum*) or distant (*A. mongolica*) distributions (Browicz and Zohary 1996) and are therefore unlikely to be represented in Öküzini.

The morphology of the endocarps of the species from the section *Chamaeamygdalus* remains largely undescribed, but we could examine some specimens of *A. georgica*. They have a broadly ovate fruit with a distinct reticulate pattern of shallow grooves. All the species from this section have a northern distribution today (*A. nana*, *A. ledebouriana*) or are endemic to regions in Georgia or China (*A. georgica*, *A. petunnikovii*) and are therefore absent from Anatolia (Browicz and Zohary 1996).

Among the *Spartioides* section, *Amygdalus arabica* has an endocarp which is smooth or has indistinct grooves near the hilum extremity and is also a rather improbable identification according to its distribution (Meikle 1966; Browicz 1972a; Browicz and Zohary 1996).

The second species of this group, *A. scoparia*, has an almost smooth endocarp and is essentially an Iranian species (Browicz and Zohary 1996).

The five species from the *Dodecandrae* subgenus have small endocarps (approx. 15 mm long) and are adapted to very arid environments. The morphological description of *Amygdalus lycioides* (Browicz 1972a) does not fit well with the shell remains from Öküzini. Moreover, it grows in Iran and only in a few localities in south Anatolia. The other four species (*A. spinosissima*, *A. eburnea*, *A. brahuica*, *A. erioclada*) have distant distributions (Browicz and Zielinski 1984; Browicz 1989; Browicz and Zohary 1996) and are therefore unlikely candidates for identification.

From the morphological comparison and the geographical distribution, a number of species could be eliminated as possible determinations. In conclusion, the two closely related species *A. orientalis* and *A. graeca* (Figs. 2, and 5) are the most probable identifications of the endocarp fragments recovered in Öküzini cave, especially with regard to the high frequency of clearly

grooved fragments, although the presence of remains belonging to *Prunus divaricata* cannot be completely excluded. According to the shape and size of the keel, *A. orientalis* is more likely, according to the modern distribution areas, *A. graeca* is expected (Ali Dönmez, pers. comm.).

In order to get a finer identification, experimental carbonisations of *Amygdalus orientalis* and *Prunus divaricata* were carried out and the anatomy of the transverse section of the endocarps compared. The examination of the histological arrangement showed a good similarity with the transverse section of the fossil endocarp fragments. The cross section from *Amygdalus orientalis* was composed of two layers: an outer layer of isodiametric cells and an inner layer of longitudinally flattened sclerotic cells (Fig. 3). Antoni (1971) has also observed this organisation in the bitter and sweet almonds (*A. communis*). Endocarps of the *Prunus divaricata* species and others identified as *Prunus divaricata* subsp. *ursina* have been observed and had three layers: the outer and the middle layers are similar to those from *Amygdalus*, the third and inner layer was composed of small isodiametric sclerotic cells. Unfortunately, this innermost layer often disappears due to carbonisation and probably erosion in the soil, so that the transverse sections of *Amygdalus orientalis* and *Prunus divaricata* can look alike and do not permit a clear distinction.

Anthracological (charcoal) analyses have shown the presence of a steppe-forest vegetation type in the neighbourhood of the site during the period from 17,600 to 12,490 cal B.C., *Amygdalus* being clearly the dominant woody taxon (Thiébaud 2002). The presence of almond trees in the vicinity of the site suggests that the endocarps were gathered locally.

Because of the fragmentation of the endocarp remains and furthermore, because of their eroded borders, we can conclude that they were probably cracked to free the seeds and then thrown into or near a fire. Other “nut remains”, like the less sturdy *Pistacia* pericarps, which do not need cracking to be consumed, were regularly preserved whole.

## Discussion

### Taxonomy and autecology of the almond plant

The almond (Rosaceae family, sub-family Prunoideae) has long been considered as a separate genus, but because it can interbreed easily with other genera (*Prunus*, *Persica*, *Cerasus*), some authors consider *Amygdalus* as a subgenus of an extended *Prunus* genus (Rehder 1940; Socias i Company 1998). This monophyletic nature of *Prunus* has been confirmed recently with phylogenetic studies (Lee and Wen 2001; Bortiri et al. 2001). However, we still use *Amygdalus* for the genus designation because it is the terminology adopted in most works about the flora of southwest Asia.

In the last 40 years, almonds were subject to intense investigations by several botanists who studied the flora and vegetation of southwest and middle Asia (Meikle 1966; Browicz 1969; Browicz 1972a, 1989). Due to the high degree of variability in almonds and the numerous ecotypes and hybrids, their taxonomy is very complex. Almost all wild species (as well as most modern cultivars) are self-incompatible, so that self-pollinisation is impossible. This results in a high degree of heterozygosity (outbreeding), expressed in a high degree of variability in morphological as well as physiological characters (Browicz and Zohary 1996; Socias i Company 1998). A great number of different species have been described, which in fact reflects the high intraspecific variability. For example Browicz (1989) listed 39 species and 19 hybrids, when some years later Browicz and Zohary (1996) reported only 26 species and some 20 hybrids or problematic taxa.

*Amygdalus orientalis* is a shrub, 0.5 to 3 m tall, usually growing in open sunny niches such as sandy hills covered with steppe or steppe-forest, on limestone cliffs or on rocky calcareous slopes. It grows between 350 and 1,500 m, however most frequently between 800 and 1,200 m (Browicz 1972a). The plant has today a large distribution area over central, south and east Anatolia. It is one of the most common wild almond species in south and central Anatolia and in northern Iraq (Browicz 1969).

*A. graeca* is a shrub or small tree between 1 and 4 m in height, which grows on limestone rocks in phrygana, between 10 and 500 m altitude. Its present distribution covers northwest, central and southwest Anatolia and some Greek islands (Davis et al. 1965–1988). It is a xerophytous and low-altitude plant.

Botanically the almond is classified among the drupes, but horticulturally, it is considered a “nut” because the edible seed is enclosed in the hard shell. *Amygdalus graeca* fruits reach their maturity in July and August, the ones from *A. orientalis* slightly later in August and September (Dönmez 1997). The plants can already reach maturity after 2 to 4 years and require some winter chilling in order to set fruit. Although the seeds are small, the fruit yield of *Amygdalus orientalis* is very good (Ak et al. 2000). The endocarps could be collected in late summer, at the same time as the hunting activities took place (Atıcı and Stutz 2002), but they could also be stored.

#### Nutritional data

The bitter taste of almond, as in other stone fruits, is due to the production of the glucoside amygdalin. This substance is not produced in the kernel, but is transported from the mother plant, so that all the kernels of a tree will have either sweet or bitter seeds (Dicenta and Garcia 1992). Amygdalin, in the presence of water and the enzyme emulsin, both present in the seed but in different cells, is hydrolysed to benzaldehyde, hydrocyanic acid (or prussic acid HCN) and glucose through crushing, chewing, or any injury to the seed. It is the hydrocyanic acid

that is bitter and toxic (Socias i Company 1998). Almost all wild almond taxa have bitter nuts, an effective chemical defence against casual herbivores. Sweet types may occur, but seemingly in low frequency (Grasselly and Crossa-Raynaud 1980; Ladizinsky 1999).

The bitter or sweet taste of the seed is a hereditary character in almond and is determined by just one gene with two alleles: one dominant, responsible for sweet flavour and one recessive, responsible for the bitter flavour (Dicenta and Garcia 1992; Socias i Company 1998). In heterozygous trees, the dominance can sometimes be altered and the bitter flavour is expressed in reduced form (Dicenta and Garcia 1992). The degree of bitterness differs also between almond species and populations (Grasselly 1976a).

The difficulty in removing the bitterness from the seeds and the rarity of sweet mutations in wild stands has brought Ladizinsky (1999) to suggest that it is inconceivable that the wild almonds could have been used as a source of food for humans before a sweet type was selected. However, nutritional data shows that, when cyanogenic plants are eaten slowly or over a period of time, there might be no symptoms of cyanide poisoning. Humans can consume 30–35 mg HCN per day when ingestion is distributed over the whole day and have the physiological ability to detoxify cyanide satisfactorily, given an adequate protein diet (Jones 1998). The toxicity is also overcome by careful food processing before they are eaten: the simple grinding of almonds in a mortar and leaving them for a few hours induces a loss of the bitter volatile HCN (evaporation temperature 24 °C) and an increased sweetness due to the glucose left behind (Jones 1998).

*Amygdalus orientalis*, like other nuts, has a high fat content. Seeds collected at maturity in the Konya region (Turkey) had 48.5% from dry weight of oil, with the mono-unsaturated oleic fatty acids dominant over the poly-unsaturated linoleic ones (Beyazoglu and Dural 1991). So, due to their high lipid content, almond kernels are a concentrated energy source. Almond is considered to be sustaining as a nutrient: the staying power conferred by a meal of almonds (here *A. communis*) and raisins is well known in Armenia (Ghandelian and Barseghian 1998). But they are more than just a source of fat. They contain several nutrients postulated to provide a protective effect against Coronary Heart Disease (CHD), such as fibre, arginine and antioxidants. Almond, like other nuts, has a cholesterol-lowering effect, and additionally its oils are anti-cancer agents (Agar et al. 1998). The nuts also contain considerable protein (ca. 20%), minerals and some vitamins.

In conclusion, if consumed in moderate quantities or if efficiently detoxified, wild almond seeds have valuable nutritional properties.



**Table 2** Archaeobotanical remains of almonds in prehistoric Anatolia

Site	Location	Date		Period	Identified as	Full description	Kind of remain(s)	Number of remains	Illustration	Archaeological context
		B.P.	B.C.							
1 Hallan Cemi	SE Anatolia	10,000		Terminal Epical-palaeolithic	<i>Amygdalus</i> sp.	Wild almond. Pitted endocarp fragments present.	Charred endocarp fragments	Many	Photograph	Several parts of the mound yielded concentrations of wild almonds. They were clearly of great economic importance despite their latent toxicity. Existence of processing of almonds, for example through roasting.
2 Çayönü	SE Anatolia	9,200–8,700	8,250–7,750	PPN	<i>Amygdalus</i> sp.	Only fragmented almond fruitstones have been recovered. The thick-walled fragments have a pitted and grooved surface and in some of them the lateral keel can be observed. The shape of some large fragments indicates that the stones must have had a length of about 2 to 2.5 cm.	Charred endocarp fragments	Fair amount	Drawing	Ash pit and unknown
3 Çafer Höyük	SE Anatolia	9,500–8,400		PPNB	Rosaceae	Thick nutshell possibly <i>Amygdalus</i>	Charred endocarp fragments	Few	-	Hearth, layers, post-holes and burnt area
4 Nevalı Çori	SE Anatolia		8,400	PPNB	<i>Amygdalus</i> sp.	Nutshell pitted, no additional description	Charred endocarp fragments	30 whole (estimate)	Drawing	-
5 Aşıklı Höyük	Central Anatolia	8,900–8,500	8,000–7,500	PPN	<i>Amygdalus</i> sp. including <i>Amygdalus orientalis</i>	Wild almond	Charred endocarp fragments	Few	-	-
6 Çatal Höyük	Central Anatolia		7,480–6,218	PN	<i>Amygdalus</i> cf. <i>orientalis</i> , <i>Amygdalus</i> type	It is a small kind. Similar to <i>Amygdalus orientalis</i> .	Charred endocarps and seeds whole and fragments	Many	-	-
7 Çatal Höyük	Central Anatolia		7,480–6,220	PN	<i>Amygdalus</i> sp., probably <i>Amygdalus orientalis</i>		Charred endocarps and seeds, whole and fragments	Many	-	Oven, burial
8 Hacilar	Central Anatolia	7,400–6,900		PN	<i>Amygdalus</i> cf. <i>orientalis</i>	Only fragments of almond shells were found at Hacilar. They were fairly thick and the stone was keeled, but not pitted. The same type was found at Çatal Höyük	Charred endocarp fragments	-	-	Well

Up to today and in spite of their potential toxicity, wild almonds are consumed and appreciated in different parts of their distribution area. For example the green, light bitter fruits of *Amygdalus orientalis* are eaten in the spring in Kızılkaya (central Anatolia) and in the Şanlıurfa province before the fruit stones harden (Ertuğ 1997; Ak et al. 2000). The very bitter seeds from the same species are also eaten when the endocarp is hard and needs to be broken (Aylan Erkal pers. comm.). Experiments showed that the bitterness decreases when the fruits are roasted (Ertuğ 1997).

Other wild almonds are also eaten, so for example the fruits of *A. bucharica*, locally consumed and used for medical and cosmetic purposes (Browicz and Zielinski 1984). The fruits of *A. arabica* are also eaten locally and sold on the market (Meikle 1966; Browicz and Zielinski 1984): the edible and the bitter seeds are even given different names. Grasselly (1976b) reports that the wild fruits of section *Euamygdalus* and *Lycioides* are often gathered by natives for the production of oil. If the almond oil is extracted by the cold-press method, amygdalin stays in the sediment (Beyazoglu and Dural 1991).

In southern California, the seeds of several *Prunus* species, in particular of *P. ilicifolia*, are eaten and even enjoyed by indigenous Indians. The bitter taste and poisonous properties seem to have been dealt with effectively by preparation methods like pounding, drying, steeping and boiling (Timbrook 1982). These *Prunus* seeds did not merely represent a more or less nutritious, storable resource, but were also important in the social life, as a readily available gift or exchange product. In northern Iraq, it has been observed that the kernels of *Prunus mahaleb* L. were also consumed in that they were baked on top of bread (Townsend and Guest 1966).

Different cyanogenic glycosides have been found in other plants widely used as food, for example the cassava plant (*Manihot esculenta*) in the Amazon (FAO 2002). Traditional processing and cooking methods of cassava can, if efficiently carried out, reduce the cyanide content to non-toxic levels. First, by disintegrating the microstructure of the cassava root, one will release the enzyme (linamarase) and bring it into contact with the glucoside (linamarin) that is converted into hydrogen cyanide (HCN). The liberated cyanide will dissolve in the water when fermentation is effected by prolonged soaking, and will evaporate when the fermented cassava is dried.

On the other hand, some tribal people in the Amazon rain forest eat as much as one kilogram of cooked fresh cassava per person per day and consume up to three litres of fermented cassava beer, but no diseases related to cassava toxicity have been reported. These tribes also consume a considerable amount of animal and fish protein and thus have high levels of sulphur-amino acids and iodine in their diet, which seem to have an antagonist effect (FAO 2002).

As already mentioned, very few Epipalaeolithic sites in Anatolia have been investigated for botanical macroremains. Beside the Epipalaeolithic almond finds from Öküzini and those similar ones from the neighbouring Karain B cave, Hallan Çemi, a terminal Epipalaeolithic site in Anatolia, yielded deposits of wild almonds in several parts of the mound (Table 2) (Rosenberg et al. 1995, 1998). Many specimens had a very eroded surface but some well-preserved ones definitely had pitted shells (pers. comm. Manon Savard). This frequency led the authors to conclude a great economic importance of the almonds. No other Epipalaeolithic plant remains have been recovered so far from Anatolia.

In the Neolithic, a site with important almond finds is Çatal Höyük. Almond remains are recurrently present in occupation horizons, middens, floors around hearth and ovens, etc, and also in deposits from an oven and “in a little heap comprising a dozen shells” in a building (Helbaek 1964; Ağcabay and Killackey 2002; Fairbairn et al. 2002). Most Neolithic plant assemblages from Anatolia regularly yield charred *Amygdalus* endocarp fragments (see Table 2). However they are absent from sites without systematic sampling, as for example Höyücek (Martinoli and Nesbitt in press), where only storage contexts have been examined. The descriptions and identifications of the almond finds are often fragmentary.

The fossil endocarp remains recovered in archaeological excavations do not attract much attention, unless they are present in important quantities or exceptionally well preserved. The review of wild almond finds from Anatolian sites, however, shows a high frequency of occurrence and gives evidence for a long tradition of use starting at least in the Epipalaeolithic. It seems that even in the Neolithic, when subsistence mainly relied on domestic plants, wild almonds were still consumed. The wild almonds of the *A. orientalis* type have been exploited in central Anatolia, when an almond with pitted shell occurs in southeast Anatolia. This is probably a reflection of the distinct landscapes present in each of these regions.

## Conclusion

The recovery and identification of endocarp remains in the Öküzini cave indicate that wild almond endocarps of the *A. orientalis/graeca* type were collected in a mature state. Although the almond remains are dominant in the Öküzini plant assemblage, we must keep in mind that the endocarp fragments are favoured for being preserved because of their hardness during the taphonomical process, and that other softer botanical remains hardly survive. The whole plant assemblage from Epipalaeolithic Öküzini and its chronological changes will be examined in a later paper (Martinoli and Jacomet in prep.). Fragmentation surfaces indicate a cracking of the nuts and therefore the use of the seeds. The almond shell, being a waste product, was often put into the fire and



charred. This matches with the frequent recovery of the endocarp fragments in charred contexts like oven and hearth remains.

We suppose that this high-energy food was eaten and could have played a remarkable role in prehistory because of its high nutritional value, its predictability and good storage and transport faculties. Almonds therefore represent an advantageous food resource, but for their toxicity. However, ethnographic sources and dietary research have shown that the consumption of cyanogenic food is possible, if in low quantity and in combination with a high meat consumption or even simple processing could have been employed to make the almonds edible. The examination of other Anatolian settlements suggests that wild almond was a widely used supply in pre-agrarian as well as in agrarian periods, but more data are eagerly awaited to strengthen this view.

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